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(54) Title: **PROCESS FOR TREATING REFINER PULP**

(57) Abstract

Process for producing lignocellulosic pulp fibers with improved properties by treating the refiner pulp with chemicals to adjust pH, treating it at high temperature and with chemical charges, and thereafter subject it to a refining step.

PROCESS FOR TREATING REFINER PULP

## FIELD OF THE INVENTION

The present invention relates to a process for producing lignocellulosic pulp in accordance with the preamble to the attached Claim 1.

## BACKGROUND OF THE INVENTION

The pulp and paper industry uses many processes to produce pulp from lignocellulosic materials such as softwoods, hardwoods or annual plants. These are used for the manufacture of several paper grades such as newsprint, speciality papers (LWC, SC, ...) and fine papers (Art, MFC, ...).

Chemical pulps used in fine papers are prepared by cooking the wood chips at elevated temperatures and pressures with various chemical agents such as  $\text{Na}_2\text{S}$  and  $\text{NaOH}$  at high pH (Kraft pulping) and  $\text{Na}_2\text{SO}_3/\text{NaHSO}_3$ , for sulfite/bisulfite pulping at neutral pH. In these processes, the purpose of the chemical agents is to degrade and dissolve the lignin and the hemicellulose material in wood to leave pure cellulose fibers in the 40-45% yield level. Following this process, chemical fibers are bleached to high levels such as 85-90% ISO-brightness. The fibers are flexible and high strength papers can be produced from them. Chemical pulps are therefore also used in producing newsprint and speciality papers to provide dry strength to the sheet to ensure good runability in the press room. There are several problems associated with chemical pulping, however, with decreasing forest resources for instance, the resulting low yield from the process implies that a substantial amount of trees must be harvested. Furthermore, chemical pulping processes require high levels of fresh water and toxic chlorinated by-products (dioxin and AOX) are found in the effluent. Odour emissions are also noteworthy. Sulfur

emissions contribute to acid rain, which is responsible for forest deterioration and depletion of the soil.

Mechanical pulps of inferior strength are also used in the manufacture of newsprint and speciality papers because of their high light scattering coefficient or opacity as well as high oil absorbancy which is required for ink acceptance during printing. In the production of these pulps, mechanical means are used. For instance, grindstones are used to defiber logs in the stone groundwood process (SG). Disc refiners are also used to defiber wood chips into pulp. Wood chips can be refined without any specific treatment such as in refiner mechanical pulping (RMP). The wood chips can also be thermally treated at temperatures between 100 to 130°C prior to being refined such as in the thermomechanical process (TMP). In these processes, approximately five percent of the wood substance that is water soluble is lost for a net yield of approximately 95%. The strength of the resulting pulps is directly related to the degree of mechanical energy applied to the fibers in the form of shear stresses in the refining zone. The energy transferred to fibers is used to increase their flexibility. The internal cell wall dislocation or fibrillation resulting from bending and torsional stresses imposed onto fibers in the refining zone enhances their flexibility, but often this increased flexibility is obtained with reduction in fiber length. It is generally recognized that there are three problems in the manufacture of refiner mechanical pulp. One is the reduced strength of the paper formed from the pulp because the fibers are chopped and abraded. The second is the high electrical demand of the refiner or high specific refining energy. The third is the low brightness of the pulp produced.

Mechanical pulps lack the desirable strength properties to replace, in whole or in part, low-yield chemical pulps, e.g. kraft or sulphite pulps, in linerboard, newsprint, tissue, printing grades and coated-base grade of paper. Consequently,

it has been an aim of the art to improve the physical and optical properties of mechanical pulps, so that such improved pulps would be used to replace low-yield chemical pulps. The major problem has been the significant quantity of electrical energy to comminute the wood chips into a useable pulp.

Impregnating wood chips with chemicals such as sulfite has been used to improve the strength and optical properties of refiner mechanical pulps. For instance, U.S. Patent 3,446,699 issued May 27, 1965 to Asplund et al. provides a method for producing mechanical and chemimechanical or semi-chemical pulps from lignocellulose-containing material, in order to provide improved quality of the fibers with improved defibration. U.S. Patent 3,558,428 issued Jan. 26, 1971 to Asplund et al. provided a method for manufacturing chemimechanical pulps involving heating and defibrating the same in an atmosphere of vapour at elevated temperature and under corresponding pressure of the impregnated chips to provide a more rapid and effective impregnation. In this chemi-thermomechanical pulping processes (CTMP) in which the yield range is between 88-92%, the wood chips are treated with relatively small amounts of sulfite and bisulfite which modifies the lignin by sulfonating it sufficiently to produce a marked change in its physical and chemical properties which give rise to brightness and strength improvement. However, the lignin is not made completely soluble in water or in the cooking liquor so that relatively high yields are obtained. Chemical impregnation of chips also results in lower debris but usually increases the long fiber content and reduces the scattering coefficient. Increases in energy requirement of 15-25% are observed to reach a given drainage or CSF level.

Falling midway between the chemical and mechanical processes are the semi-chemical and chemi-mechanical pulping processes (CMP). The yield range of the resulting pulps is between 60-85% so that good pulp properties are achieved at low refining

energy by cooking the wood chips (or other cellulosic material) under severe conditions. Typical temperatures are in the 160-240°C range with high chemical charges to degrade a great deal of the lignin and hemicellulose. Cooking times range between one to four hours. As an example, U. S. Patent 4,116,758 issued Sept. 26, 1978 to M.J. Ford provided a process for producing high-yield chemimechanical pulps from woody lignocellulose material by treatment with an aqueous solution of a mixture of sulfite and bisulfite, to provide a pulp which can be readily defibered by customary mechanical means. The resulting pulp has different characteristics depending on the yield and refining energy applied as demonstrated by M. Barbe et al., Journal of Pulp and Paper Science, 12(5): J141-146 (September 1986).

An alternate approach to improve the quality of mechanical pulps has been to treat the refiner pulp fibers. Two processes are currently used commercially. In the first process, described by A. Barnet et al., Pulp and Paper Canada 81, T255-T260 (1980), TMP pulp fibers are being treated at 160°C for 45-60 minutes in a reactor with sodium sulfite charges of 12-14% at pH of 9.8. The yield obtained is in the range of 85-88%. The refining energy to a given freeness is reduced while the strength properties are improved. The high chemical charges, low yield and therefore high effluent loads combined with the high cost for a reactor of appreciable size, as well as the dewatering or washing equipment required, offsets the benefits achieved. Therefore, this process alternative has not received wide commercial acceptance in the industry. In the second process, described by M. Barbe et al., World Pulp and Paper Technology 1991, Frank Roberts, editor, Sterling Publications International Limited, London (1991), CTMP pulp fibers are being treated at medium consistency (12%) and at 60°C for 120 minutes with an alkaline peroxide liquor at pH of 10-11.

The yield obtained with this process is in the range of 80-85%. Savings in refining energy to reach a given freeness are

obtained. The drawbacks of this latter process are similar to those of the first process alternative. The low yield, high effluent loads and chemical charges combined with the high costs for bleaching towers with two hours retention time, with their discharge mechanisms as well as the cost for the dewatering or washing equipment required, offsets the benefits achieved. Therefore, this process alternative has not received wide commercial acceptance in the industry.

The low brightness of mechanical pulps is clearly a major problem which has limited their use in different paper grades. Several processes are currently employed in the pulp and paper industry to bleach mechanical or chemithermomechanical pulps. One process uses a reducing agent such as dithionite or sodium and zinc hydrosulfite (Y) to brighten or bleach the pulps. With this bleaching chemical moderate gains of 4 to 10 points are obtained. Maximum brightness levels of 68 to 70% ISO can be reached with the addition of approximately 1% to 1.25% on o.d. pulp of sodium hydrosulfite. The process is usually carried out in an aqueous phase at 3 to 5% consistency, a pH of 4.5 to 6.0, a temperature of about 60°C and a retention time of up to one hour. The use of a chelating or sequestering agent such as sodium tripolyphosphate (STPP) to remove naturally occurring trace metals is recommended. Peroxide (P) is also employed for bleaching. The process is carried out in a single tower or in two bleaching towers. In both cases, the bleaching is done at a pulp consistency of 15 to 35%, moderate temperatures of 50 to 70°C, and retention times of two to three hours for each stage. Stabilizers such as sodium silicate and magnesium sulfate are added to the bleach liquor to prevent peroxide decomposition. Sodium hydroxide is also used to maintain an alkaline pH of 9.5 to 11 so as to increase the concentration of the perhydroxyl ion OOH which is believed to be the active bleaching agent. Furthermore, pulps are normally pretreated at low consistency with organic chelating agents such as sodium diethylenetriamine penta-acetate (DTPA) to remove trace metals.

All of the above bleaching processes involve the addition of high chemical charges and high costs in order to achieve the desired brightness levels. However, these permit to extend the use of the mechanical or chemimechanical pulps in a wide range of paper products. High capital costs in equipment are required.

It is well known that the physical properties of wood pulps are strongly influenced by the flexibility of the individual fibers. In the papermaking process, the fibers are brought into close contact with each other by surface tension forces in the water removal process or during the pressing stages of the process. Flexible fibers therefore lead to better bonding and improved strength. Natural wood fibers are inflexible due to the presence of large amounts (20-30% by weight) of lignin and crystalline cellulose (30-40% by weight). All of the prior art indicate that fiber flexibility has been improved in conventional mechanical pulping by applying mechanical energy to the fibers and in chemical or semichemical or chemimechanical pulping processes by removing part, or nearly all, of the lignin or in some other cases by modifying its chemical nature with sulfonation in addition to the mechanical energy. However, in mechanical pulping the increased fiber flexibility and sheet strength is limited as the increase in flexibility is done with cell wall dislocations that reduce fiber strength and fiber length. In chemimechanical pulping, or with the existing pulp fiber treatment process, the increased fiber flexibility and sheet strength is obtained by reducing the yield of the pulp.

It is therefore an object of the present invention to provide a process which permits the treatment of lignocellulosic materials so as to render the fibers flexible and conformable with low refining energy while improving the strength and brightness of the resulting pulp in addition to maintaining the materials yield for the production of pulp from wood chips and

other lignocellulosic materials. In addition to the savings obtained with low refining energy, saving can also be obtained in capital cost requirements and in bleaching chemicals when the treated pulps are bleached to high levels with the current state of the art bleaching technology. Conversely, high brightness levels can be reached at a given bleaching chemical charge, therefore permitting to improve the quality of mechanical pulps to extend their use in the production of high quality paper grades in replacement of chemical fibers.

This object is obtained by the following process of the type described in the preamble to Claim 1 which is characterized by the following steps:

- a) mixing the lignocellulosic material with a buffer or chemical solution in a high shear mixer-reactor so as to adjust the pH of the pulp, while maintaining the pulp at high consistency,
- b) submitting the pulp to high temperature for times and chemical charges sufficient to reduce the long range crystalline structure of the cellulose component of wood, and
- c) subsequent by subjecting the lignocellulosic pulp fibers to refining to produce a pulp with the desired end-product properties.

The present invention will be explained in more detail with reference to the drawings of which:

Fig. 1 shows the energy reductions obtained when pulps are treated in accordance with the present invention as a function of the final pH of the pulp.

Fig. 2 shows the energy reductions obtained as a function of the total ionic content or yield,

Fig. 3 shows the energy reduction/increase to be expected upon changes or variation in the sulfonate content of the fibers obtained with the present state of the art CTMP or CMP technology,

Figs. 4 and 5 are process flow diagrams illustrating the various steps of a continuous operation in which pulps are treated according to the present invention.

While the invention is not limited to any theory, it is believed that the process provides the savings in refining energy and improved properties by reducing the long range crystallinity of cellulose and by the chemical degradation of the lignin, hemicellulose and cellulose components of wood. Figure 1, showing energy reductions obtained following the treatment of the pulps according to the present invention, as a function of the final pH of the pulp, as well as Figure 2 showing energy reductions obtained as a function of the total ionic content or yield, indicate that savings can be obtained at low ionic content or high yield with treatments at low pH as well as at high total ionic content and high pH. Under low pH and ionic content conditions, it is believed that changes in the long range crystallinity of the crystalline structure of the cellulose prevails to give the savings in refining energy. The chemicals or buffers used inhibit the acid hydrolysis of the polysaccharides and therefore preserves fiber strength. At high pH or high ionic content, the chemical degradation of the lignin, hemicellulose and cellulose may prevail in addition to the changes in the crystalline structure of cellulose. Figure 3 shows the energy reduction/increase to be expected upon changes or variations in the sulfonate content of the fibers obtained with the present state of the art CTMP or CMP technology.

Figure 4 describes an application of the process by which a refined pulp obtained directly at the outlet of a refiner (1) is blown in a high shear mixer (2) in which a buffer or a chemical solution is added to adjust the pH of the pulp. The conditions for the treatment temperature or pressure as well as the desired retention time and chemical charge in the high shear mixer (2) are to be selected according to the initial pulp pH, wood species and desired benefits in either strength, optical or refining energy reduction to be sought. Subsequently, the treated pulp is mechanically defiberized in a second refiner (3) which blows the pulp to a pressurized or atmospheric cyclone (4).

Figure 5 describes an application of the process by which a refiner pulp obtained at the discharge of a dewatering device such as a screw press (5), is fed with a pulp plug screw (6) into the high shear mixer (7). Buffers or a chemical solution is added to adjust the pH of the pulp while the treatment temperature or pressure as well as the desired retention time and chemical charge is set to achieve the desired benefits. Subsequently, the treated pulp is mechanically defibered in a refiner (8) and blown into a pressurized or atmospheric cyclone (9).

THE FOLLOWING EXAMPLES ARE GIVEN TO ILLUSTRATE MORE CLEARLY VARIOUS EMBODIMENTS OF THE INVENTION.

Example 1

In this example, as well as in subsequent examples, the following experimental procedure was used for the treatment of pulps. The different chemical agents were mixed with a refined pulp in a commercial high shear mixer, treated in a digester and subsequently refined on a 30 cm single disc refiner. The control pulps coded CB3N were only thermally treated in the digester prior to refining. The control pulps coded C-6N were

simply refined in the single disc refiner without thermal treatment.

This example is intended to illustrate that when pulp fibers are treated in the presence of acids or bases to adjust the pH, as described for aspects of this invention, refining energy is reduced appreciably while the strength properties are improved.

Table 1 gives the quality of pulps treated compared to the treated pulp without buffers or chemicals (coded CB-3N) and the untreated pulp (coded C-6N).

The pulps coded C-6N give the properties of a pulp as produced by the current state of the art. The pulp coded CB-3N gives the properties of a pulp submitted to a thermal treatment without the addition of a buffer. The pulps coded A1-4N, A2-4N and B-4N give the properties of a pulp submitted to a thermal treatment with the addition of NaOH or H<sub>2</sub>SO<sub>4</sub>, to adjust the pH as per the precept of this invention. It can be observed that reduction of refining energy of 26 to 64% are obtained compared to the untreated pulp. Higher energy reductions are obtained at high and low pH adjustment. It is preferable to treat the pulp at high pH levels to obtain high strength properties such as tensile index and breaking length. However, the tear index remains low. The pH adjustment allows the optimization of different pulp quality under conditions in order to obtain high yield pulps. Table 2 shows the effect of conventional peroxide bleaching on the pulp and paper properties for the pulps treated with H<sub>2</sub>SO<sub>4</sub>, and the pulp treated without buffers or chemicals. The pulps treated at low pH show higher brightness level compared to the pulp treated without buffers or chemicals at a given chemical charge and higher brightness level is also reached following a peroxide bleaching stage. Therefore, reductions in peroxide consumption are expected to be reached at a given brightness level when the pulps are treated at low

pH with buffers, compared to pulps treated without buffers or chemicals.

#### Example 2

This example illustrates the effect of pH of treatment upon adjustment with  $\text{CO}_2$  and calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ).

Table 3 gives the quality of pulps treated compared to the treated pulp without buffers or chemicals (coded CB-3N) and the untreated pulp (coded C-6N).

The pulps coded C-6N give the properties of a pulp produced by the current state of the art. The pulp coded CB-3N gives the properties of a pulp submitted to a thermal treatment without the addition of a buffer. The pulps coded H2-5N and H3-6N give the properties of a pulp submitted to a thermal treatment with the addition of  $\text{CO}_2$  and  $\text{CO}_2/\text{Ca}(\text{OH})_2$ , to adjust the pH as per the precept of this invention. It can be observed that refining energy reductions of 18 to 28% are obtained compared to the untreated pulps while maintaining a high yield. The strength properties of the treated pulps are lower compared to the untreated pulps. However, with the heat treatment, reductions in energy consumption are obtained with the use of  $\text{CO}_2$  or  $\text{CO}_2/\text{Ca}(\text{OH})_2$ , together with improved strength properties and brightness of the pulps. In addition to the above benefits, the combined use of the  $\text{CO}_2$  or  $\text{CO}_2/\text{Ca}(\text{OH})_2$ , give rise to the formation of  $\text{CaCO}_3$ , which is used as a filter in the pulp and paper industry to confer high opacity to paper.

#### Example 3

This example illustrates the effect of sodium sulfite ( $\text{Na}_2\text{SO}_3$ ) liquor used to control the pH of the heat treatment. In this example, pulps were heat treated with  $\text{H}_2\text{SO}_4$  and  $\text{NaOH}$  in combination with the  $\text{Na}_2\text{SO}_3$ , to control the pH.

Table 4 gives the quality of pulps treated compared to the treated pulp without buffers or chemicals (coded CB-3N) and the untreated pulp (coded C-6N).

The pulps coded C-6N give the properties of a pulp produced by the current state of the art. The pulp coded CB-3N gives the properties of a pulp submitted to a thermal treatment without the addition of a buffer. The pulps coded D1-3N, D2-7N, and D3-7N give the properties of a pulp submitted to a thermal treatment with the addition of  $\text{Na}_2\text{SO}_4$ , and  $\text{H}_2\text{SO}_4$ , or  $\text{NaOH}$ , to adjust the pH as per the precept of this invention.

It can be observed that refining energy reductions of 30 to 45% are obtained compared to the untreated pulps. The maximum energy reductions are obtained at low and high pH. It is preferable to treat the pulp at high pH to reach high strength properties such as tensile index or breaking length. However, the tear index is lower compared to untreated pulps. The pH adjustment allows the optimization of different pulp quality under different conditions while the high yield of the pulps is maintained. Table 5 shows the effect of conventional peroxide bleaching on the pulp and paper properties for the pulps treated with  $\text{Na}_2\text{SO}_4$ , at low pH and the pulp treated without buffers or chemicals. The pulps treated at low pH show higher brightness level compared to the pulp treated without buffers or chemicals. Higher brightness level is also reached following a peroxide bleaching stage. Therefore, reductions in peroxide consumption are also to be expected to reach a given brightness level when the pulps are treated with  $\text{Na}_2\text{SO}_4$ , at low pH compared to pulp treated without buffers or chemicals.

#### Example 4

This example illustrates the effect of reducing agents such as sodium hydrosulfite ( $\text{Na}_2\text{S}_2\text{O}_4$ ), sodium borohydride ( $\text{NaBH}_4$ ) and

formamidine sulfinic acid (FAS) to control the pH of the pulp during heat treatment.

Table 6 gives the quality of pulps treated compared to the treated pulp without buffers or chemicals (coded CB-3N) and the untreated pulp (coded C-6N).

The pulps coded C-6N give the properties of a pulp produced by the current state of the art. The pulp coded CB-3N gives the properties of a pulp submitted to a thermal treatment without the addition of a buffer. The pulps coded G1-5N, G2-4N, G3-5N, and H1-5N give the properties of a pulp submitted to a thermal treatment with the addition of  $\text{Na}_2\text{S}_2\text{O}_4$  and  $\text{NaBH}_4$  or FAS, to adjust the pH as per the precept of this invention.

It can be observed that refining energy reductions of 30 to 35% are obtained compared to the untreated pulps while maintaining a high yield. The strength properties of the treated pulps are lower compared to the untreated pulps. However, as a heat treatment reduces the energy consumption, it is shown that the addition of reducing agents may also improve the strength properties of the pulps. Under acidic conditions, the brightness of the pulps is also improved compared to treated pulps without buffers or chemicals. Table 7 shows the effect of conventional peroxide bleaching on the pulp and paper properties for the pulps treated with  $\text{NaBH}_4$  at high pH and the pulp treated without buffers or chemicals. The pulps treated at high pH show similar brightness level compared to the pulp treated without buffers or chemicals. However, higher brightness levels (approximately 10 points) are reached following a peroxide bleaching stage. The pulps treated with a reducing agent have a better brightness response to peroxide bleaching compared to pulp treated with heat only. Therefore, reductions in peroxide are also expected to reach a given brightness level when the pulps are treated with a reducing

agent at high pH compared to pulps treated without buffers or chemicals.

Example 5

This example illustrates the effect of oxidizing agents such as peroxide ( $H_2O_2$ ), oxygen ( $O_2$ ) and a mixture of peroxide and oxygen. In this example, the pH of the pulps were adjusted with NaOH used with the  $H_2O_2$  solution.

Table 8 gives the quality of pulps treated compared to the treated pulp without buffers or chemicals (coded CB-3N) and the untreated pulp (coded C-6N).

The pulps coded C-6N give the properties of a pulp produced by the current state of the art. The pulp coded CB-3N gives the properties of a pulp submitted to a thermal treatment without the addition of a buffer. The pulps coded D1-5N, F2-4N, and F3-4N give the properties of a pulp submitted to a thermal treatment with the addition of oxidizing agent and NaOH.

It can be observed that refining energy reductions of 11 to 27% are obtained compared to the untreated pulps. The maximum energy reductions are obtained at high pH. It is preferable to treat the pulp at high pH levels to obtain high strength properties such as tensile index and breaking length. The pH adjustment allows the optimization of different pulp quality under conditions while high yield pulps are produced. In order to reduce the refining energy and to improve the strength properties as well as the brightness of the pulps, it is preferable to combine the thermal treatment with the addition of oxidizing agents. However, the tear index remains lower. Table 9 shows the effect of conventional peroxide bleaching on the pulp and paper properties for the pulps treated with oxidizing agents and the pulp treated without buffers or chemicals. The pulps treated with oxidizing agents show higher

brightness level compared to the pulp treated without buffers or chemicals. Higher brightness levels are also reached following a peroxide bleaching stage. Therefore, reductions in peroxide are also expected at a given brightness level when the pulps are treated with a reducing agent compared to the pulps treated without buffers or chemicals.

#### Example 6

This example illustrates the effect of oxidizing agents such as peracids made from a mixture of peroxymonosulfuric acid or Caro's acid ( $H_2SO_5$ ) and peracetic acid ( $CH_3CO_2H$ ). In this example, pulps were treated with adjustment of the pH with NaOH in combination with the mixture of  $H_2SO_5:CH_3CO_2H$ .

Table 10 gives the quality of pulps treated compared to the treated pulp without buffers or chemicals (coded CB-3N) and the untreated pulp (coded C-6N).

The pulps coded C-6N give the properties of a pulp produced by the current state of the art. The pulp coded CB-3N gives the properties of a pulp submitted to a thermal treatment without the addition of a buffer. The pulps coded I1-4N, I2-3N, and I3-4N give the properties of a pulp submitted to a thermal treatment with the addition of oxidizing such as a mixture of  $H_2SO_5$ , NaOH, and NaOH to adjust the pH as per the precept of this invention.

It can be observed that refining energy reductions of approximately 20% are obtained compared to the untreated pulps. To obtain full benefits in energy reduction, in addition to strength and optical properties, it is preferable to combine the heat treatment with the addition of oxidizing agents such as a mixture of Caro's acid and peracetic acid under acidic conditions. Table 11 shows the effect of conventional peroxide bleaching on the pulp and paper properties for the pulps

treated with oxidizing agents and the pulp treated without buffers or chemicals. The pulps treated show lower brightness level compared to the pulp treated without buffers or chemicals but higher brightness level is reached following a peroxide bleaching stage. Therefore, reductions in peroxide are also expected at a given brightness level when the pulps are treated with peracid agents compared to the pulps treated without buffers and chemicals. The pH adjustment allows the optimization of different pulp quality under selected conditions while retaining their yield pulps.

Table I

The effect of pH adjusted with buffers

Codes	Treated as per this invention with buffers or chemicals			Treated without buffers or chemicals			Untreated	
	A1-4N	A2-4N	B-4N	CN-3N	C-6N	C-6N	C-6N	C-6N
Conditions								
Initial pH	6.0	6.0	6.0	6.0	6.0	6.0		
Final pH	13	6.95	3.37	3.64				
NaOH(%)	11.98	1.93	0	0	0	0		
H <sub>2</sub> SO <sub>4</sub> (%)	0	0	0.12	0	0	0		
CO <sub>2</sub> (%)	0	0	0	0	0	0		
Global Yield (%)	84.4	94.4	94.9	91.8			99.6	
Energy (kWh/ODMT)	494.7	508.62	1103.7	974.14	693.6	750	709	777.2
<u>Pulp Properties</u>								
Wireness (ml)	126	150	137	150	168	150	149	150
R14	10.3	10.3	13.5	12.4	13.5	12.4	11.5	127
14/28	31.4	32.4	32.4	32.3	32.3	32.3	31.6	13.9
28/48	24.8	23.9	23.9	23.3	23.3	23.3	21.3	28.9
48/100	13.1	11.9	11.9	11.4	11.4	11.4	12.3	25.8
100/200	4.8	4.2	4.2	4.1	4.1	4.1	4.4	11.2
P200	15.57	14.10	14.10	15.37	15.37	15.37	18.91	4.1
Fiber Length (mm)	1.39	1.48	1.43	1.43	1.43	1.43	1.38	16.10
Total Ionic Content (mmol/kg)	264.46	174.34	99.72	93.51				
<u>Dry Sheet Properties</u>								
Structural								
Basis Weight(g/m <sup>2</sup> )	57.82	55.78	60.30	58.61				55.07
Dull(cm <sup>2</sup> /g)	2.12	2.09	2.48	2.55				2.85
Density (kg/m <sup>3</sup> )	472.38	402.43	386.52	391.76				350.76
Strength Properties								
Tensile Index(N/m <sup>2</sup> )	66.59	62.96	63.32	58.52	49.63	48.07	47.04	60.80
Breaking Length(km)	6.79	6.44	6.46	5.70	5.10	5.04	4.90	4.74
Stretch(%)	2.06	2.27	2.29	2.04	2.17	2.23	2.41	2.25
Work to Rupture (cm <sup>2</sup> g)	826	845	845	663	663	718	718	763
Burst Index (kPa·m <sup>3</sup> /g)	3.79	3.69	3.52	3.48	2.93	3.02	2.77	2.67
Tear Index (mN·m <sup>2</sup> /g)	6.04	6.45	8.90	8.97	9.24	8.39	8.37	8.12
Runnability (N <sup>2</sup> ·m <sup>2</sup> /100kg)	402.19	406.09	563.57	524.92	461.82	416.40	402.35	381.96
Optical Properties								
ISO Brightness(8.457mm, %)	21.9	21.5	29.6	29	44.1	43.5	36.8	37.5
Opacity(%)	97.8	97.8	98.4	97.2	97.2	99.0	98.4	93.6
Scattering Coeff. (cm <sup>2</sup> /g)	509.6	512.2	369.8	373.4	509.6	512.2	505.0	496.3
Absorption Coeff. (cm <sup>2</sup> /g)	131.7		121.2	71.4			115.9	33.4

Table 2  
The effect of peroxide bleaching on pulp and paper properties of treated and controlled pulps

Undes Treatment	Treated as per this invention with buffers and chemicals				Treated without buffers or chemicals	
	B-4N 0.12% $\text{H}_2\text{SO}_4$	B-4N-A	B-4N-B	CB-3N	CB-3N-B	
<u>Conditions</u>						
M <sub>2</sub> SO <sub>4</sub> (%)	0	0.05	0.05	0	0.05	0.05
DIPA (%)	0	0.4	0.4	0	0.4	0.4
NaOH/(10 <sup>-2</sup> ), H <sub>2</sub> O <sub>2</sub> (%)	0	0.7	0.7	0	0.7	0.7
Silicate/(10 <sup>-2</sup> ), H <sub>2</sub> O <sub>2</sub> (%)	0	1.5	1.5	0	1.5	1.5
Consistency (%)	0	2.5	5	0	5	5
Temperature (°C)	0	25	25	0	25	25
Retention time (min.)	0	80 120	80 120	0	80	80
Global Yield (%)	94.9	91.9	89.1	91.8	87.0	120
Energy (kWh/ODMT)	693.6			709		
<u>Dry Sheet Properties</u>						
Structural						
Basis Weight (g/m <sup>2</sup> )	60.30 2.59 386.52	59.45 2.58 387.04	59.15 2.65 377.22	58.61 2.55 391.76	60.45 2.23 449.13	60.45 2.23 449.13
Bulk (cm <sup>3</sup> /g)						
Density (kg/m <sup>3</sup> )						
Strength Properties						
Tensile Index (N.m/g)	49.98 5.10 2.17	44.68 4.56 2.16	51.87 5.29 2.15	48.07 4.9 2.41	55.06 5.62 2.12	55.06 5.62 449.13
Breaking Length (km)						
Stretch (%)						
Work to Rupture (cm <sup>2</sup> /g)						
Burst Index (kPa <sup>2</sup> .m <sup>3</sup> /g <sup>2</sup> )	66.3 2.93 2.92	61.1 2.45 2.41	69.5 2.94 2.86	71.8 2.77 8.37	74.7 2.96 7.82	74.7 2.96 430.57
Tear Index (mN <sup>2</sup> .m <sup>3</sup> /g <sup>2</sup> )	9.24 46.82	8.61 384.69	8.36 433.63	8.37 402.35		
Runnability (N <sup>2</sup> .m <sup>3</sup> /1000g <sup>2</sup> )						
Optical Properties						
ISO Brightness (R-457nm, %)	44.1 97.2 509.6 71.4	58.9 90 442.3 20.2	65.4 86.1 418.6 12.0	36.8 99 505 115.9	52.9 92.1 436.4 29.6	52.9 92.1 436.4 29.6
Opacity (%)						
Scattering Coeff. (cm <sup>2</sup> /g)						
Absorption Coeff. (cm <sup>-1</sup> /g)						
ISO Brightness-Pad	48.51 83.37 1.28 14.95	63.72 92.07 -1.18 15.15	70.78 91.2 -1.91 12.67	37.07 77.52 3.15 18.24	59.01 90.64 -0.82 17.01	59.01 90.64 -0.82 17.01

a

b

Table 3  
The effect of pH adjusted with  $\text{CO}_2$  and  $\text{Ca}(\text{OH})_2$

Codes	Treated as per this invention with buffers or chemicals		Treated without buffers or chemicals		Untreated	
	II2.5N	II3.6N	CH.3N	CH.6N	CH.3N	CH.6N
Conditions						
Initial pH	6.0	6.0	6.0	6.0		
Final pH	4.11	5.61	3.64	0	0	0
$\text{CO}_2$ (%)	5	3.75	0	0	0	0
$\text{Ca}(\text{OH})_2$ (%)	0	0.39	0	0	0	0
Global Yield (%)	96.7	98.1	91.8	99		
Energy (kWh/ODMT)	962	948.2	1012	1072.5	709	777.2
					1638.7	1310.9
Pulp Properties						
Freeness (ml)	154	150	155	149	150	127
R14	12.2	12.4	13.7	11.5	13.9	150
10/28	30.9	31.8	31.2	31.6	28.9	11.8
28/18	23.3	24.3	21.3	25.8		
48/100	12.9	13.2	12.3	11.2		
100/200	4.9	4.9	4.4	4.1		
1200	15.80	12.14	18.91	16.10		
Fiber Length (mm)	1.42	1.49	1.47	1.44		
Total Ionic Content (mmol/kg)	103.93	115.94	93.51	137.98		
DRY Sheet Properties						
Structural Basis Weight (g/m <sup>2</sup> )	59.50	60.69	58.61	55.07		
Bulk (cm <sup>3</sup> /kg)	2.77	2.70	2.74	2.55	2.85	2.87
Density (kg/m <sup>3</sup> )	361.27	353.45	391.76	350.76		
Strength Properties						
Tensile Index (N.m/g)	48.06	49.63	52.75	48.07	47.04	60.80
Breaking Length (km)	4.90	5.38	4.90	4.74	6.20	5.70
Stretch (ε <sub>ε</sub> )	2.28	2.24	2.34	2.41	2.25	2.24
Wet to Dry Strength (cm <sup>2</sup> .g)	681	778	718	763		
Burst Index (kPa.m <sup>2</sup> /g)	3.04	2.94	3.05	2.77	2.67	3.24
Tear Index (mm <sup>2</sup> .m <sup>-1</sup> /g)	9.89	8.88	8.21	8.17	8.12	10.13
Runnability (N <sup>2</sup> .m <sup>2</sup> /1000g <sup>2</sup> )	475.31	410.71	421.66	402.35	381.96	628.06
Optical Properties						
IR Brightness (R 457 nm, %)	42.7	42.5	40.4	40	37.5	56.1
Opacity (%)	96.7	96.5	97.5	97.2	99.0	93.6
Scattering Coeff. (cm <sup>2</sup> /g)	422.5	420.3	425.5	410.9	505.0	468.3
Absorption Coeff. (cm <sup>2</sup> /g)	69.9		82.8	115.9	496.3	33.4

**Table 4**  
**The effect of reducing agents on pulp pH and pulp and paper properties of the treated and controlled pulps**

Codes	Treated as per this invention with buffers or chemicals				Treated without buffers or chemicals		Untreated	
	D1-3N	D2-7N	D1-7N	CB-3N	CB-3N	C-6N	C-6N	
Conditions								
Initial pH	6.0	6.0	6.0	6.0	6.0	6.0	6.0	
Final pH	2.07	6.29	12.16	3.64	11.55	3.64	0	
NaOH(%)	0	0	0	0	0	0	0	
H <sub>2</sub> SO <sub>4</sub> (%)	2.45	6	6	6	6	6	0	
Na <sub>2</sub> SO <sub>4</sub>								
Global Yield (%)	94	95.4	92.3	91.8	99.6			
Energy (kWh/ODMT)	55.8	709.8	892	901.6	871	797.9	709	1310.9
<b>Pulp Properties</b>								
Fiber length (mm)	162	150	170	150	150	149	150	150
1:1.4	12.7	12.1	14.3	13.2	14.2	11.5	12.7	11.8
1:1.28	31.9	32.3	32.3	31.3	31.6	28.9		
28:1R	33.0	26.5	26.5	24.4	21.3	25.8		
1R:1.0	11.4	12.1	12.0	12.0	12.3	11.2		
100:2:10	4.1	4.1	4.3	3.8	4.4	4.1		
1:2:10	6.57	10.55	10.55	14.31	18.91	16.10		
Fiber Length (mm)	1.54	1.39	1.53	1.48	1.38	1.44		
Total Ionic Content (mmol/kg)	183.06	280.79	394.59	93.51	137.98			
<b>Dry Sheet Properties</b>								
Structural								
Basis Weight (g/m <sup>2</sup> )	59.53	59.96	59.96	58.61	55.07			
Bulk (cm <sup>3</sup> /g)	2.50	2.58	2.23	2.55	2.85			
Density (kg/m <sup>3</sup> )	401.97	387.34	417.77	391.76	350.76			
Strength Properties								
Tensile Index (N/mm <sup>2</sup> )	51.18	50.83	57.98	61.25	68.07	47.04	60.80	54.82
Breaking Length (km)	5.24	5.92	6.95	6.5	4.90	4.74	6.20	5.70
Stretch(%)	2.39	2.25	2.17	2.13	2.33	2.11	2.25	2.14
Work to Rupture (cm <sup>2</sup> )	768	766	997	718	763			
Bust Index (kPa·m <sup>1/2</sup> /g)	3.14	3.13	3.47	3.96	3.92	2.77	3.61	3.24
Tear Index (mN·m <sup>1/2</sup> /g)	7.80	7.50	8.50	8.38	7.11	8.17	10.13	10
Rimability (N·m <sup>1/2</sup> /100g)	400.76	381.22	492.83	513.28	501.01	402.35	628.06	518.2
Optical Properties								
ISO Brightness (K-457nm, %)	45.5	45.6	51.0	52.5	26.7	36.8	37.5	56.1
Opacity(%)	99.2	97.1	91.4	93.7	97.9	98.4	91.6	55
Scattering (coeff. (cm <sup>2</sup> /g)	506.5	509.0	414.8	427.7	347.2	505.0	468.3	92.9
Absorption Coeff. (cm/g)	102.4	39.5	112.4	115.9				568.1

**Table 5**  
**The effect of peroxide bleaching on pulp and paper properties of treated and controlled pulps**

Codes Treatment	Treated as per this invention with buffers or chemicals			Treated without buffers or chemicals		
	DI-JN	2.45% H <sub>2</sub> SO <sub>4</sub> + 6% Na <sub>2</sub> SO <sub>4</sub>	DI-JN-B	CB-JN	CB-JN-B	
Conditions						
Na <sub>2</sub> SO <sub>4</sub> (%)	0	0.05	0	0.05	0.05	
DIPA (%)	0	0.4	0	0.4	0.4	
NaOH/H <sub>2</sub> O <sub>2</sub>	0	0.7	0	0.7	0.7	
Silicate/Li <sub>2</sub> O <sub>2</sub>	0	1.5	0	1.5	1.5	
H <sub>2</sub> O <sub>2</sub> (%)	0	5	0	5	5	
Consistency (%)	0	25	0	25	25	
Temperature (°C)	0	80	0	80	80	
Retention time (min.)	0	120	0	120	120	
Global Yield (%)	94.0	89.2	91.8	91.8	87.0	
Energy (KWh/ODMT)	558		709			
<b>Dry Sheet Properties</b>						
Structural						
Basis Weight (g/m <sup>2</sup> )	60.58	58.62	58.61	60.45		
Bulk (cm <sup>3</sup> /g)	2.49	2.44	2.55	2.23		
Density (kg/m <sup>3</sup> )	401.97	410.5	391.76	449.13		
Strength Properties						
Tensile Index (N/mm/g)	51.38	61.59	48.07	55.06		
Breaking Length (km)	5.24	6.28	4.9	5.62		
Stretch (%)	2.39	2.08	2.41	2.12		
Work to Rupture (cm <sup>2</sup> g)	768	782	718	747		
Burst Index (kPa m <sup>2</sup> /g)	3.14	3.4	2.77	2.96		
Tear Index (mN <sup>2</sup> m <sup>-1</sup> /g)	7.80	7.03	8.37	7.82		
Runnability (N <sup>2</sup> m <sup>-1</sup> /1000g)	400.76	432.98	402.35	430.57		
Optical Properties						
ISO Brightness (8-457nm, %)	45.5	62.8	36.8	52.9		
Opacity (%)	99.2	86.5	99	92.3		
Scattering Coeff. (cm <sup>2</sup> /g)	506.5	381.3	505	436.4		
Absorption Coeff. (cm <sup>2</sup> /g)	102.4	15.3	115.9	29.6		
ISO-Brightness-Pad	52.38	72.26	37.07	59.02		
1.	85.11	94.26	77.562	90.64		
a.	0.17	2.26	3.15	0.82		
b.	13.91	11.58	18.24	17.01		

Table 6  
The effect of reducing agents on pulp pH and pulp and paper

Conditions	Treated pulps as per this invention with buffers and chemicals					Treated without buffers or chemicals		Untreated	
	G1-5N	G2-4N	G3-5N	III-5N	CB-3N	C-6N			
Initial pH	6.0	6.0	6.0	6.0	6.0	6.0			
Final pH	11.92	12	7.53	3.7	3.64	0	0	0	0
NaBH <sub>4</sub> or Na <sub>2</sub> S <sub>2</sub> O <sub>8</sub> (%)	1.50	0	0	1.53	0	0	0	0	0
Na <sub>2</sub> SO <sub>3</sub> (%)	0	0	0	0.30	0	0	0	0	0
NaOII (%)	0	0	0.5	0	0	0	0	0	0
Global Yield (%)	96.5	91.2	97	97.4	91.4	99			
Energy (kWh/ODMT)	976.9	896.4	1070	834.2	1102	953.4	709	777.2	1366
<b>Pulp Properties</b>									
Thickness (m)	148	150	135	150	126	144	149	150	127
R14	11.2	11.3	8.9	9.0	13.1	13.4	11.5	13.9	150
14/28	32.9	32.0	30.8	30.8	31.9	31.7	31.6	28.9	11.8
28/48	25.1	25.5	23.8	23.8	24.4	24.4	21.3	25.8	
48/100	13.3	14.7	12.4	12.4	13.0	13.0	12.3	11.2	
100/200	4.9	5.5	4.8	4.8	3.5	3.5	4.4	4.1	
R200	12.63	13.37	15.10	15.10	14.51	14.51	18.91	16.10	
Fiber Length (mm)	1.44	1.37	1.36	1.44	1.46	1.46	1.38	1.44	
Total Ionic content (mmol/kg)	182.34	190.3	137.06	126.01	126.01	126.01	93.51	137.98	143
<b>Dry Sheet Properties</b>									
Structural									
Basis Weight (g/m <sup>2</sup> )	61.37	2.41	59.99	61.43	61.20	58.61	55.07		
Bulk (cm <sup>3</sup> /g)	2.47	2.28	2.33	2.55	2.76	2.55	2.85		
Density (kg/m <sup>3</sup> )	405.64	418.50	391.55	2.67	362.34	391.76	350.76		
Strength Properties									
Tensile Index (N/m)	58.23	56.30	58.73	58.46	57.04	50.74	47.04	60.80	54.82
Breaking Length (km)	5.94	2.15	5.99	5.97	5.27	4.90	4.74	6.20	5.70
Stretch (%)	2.18	2.15	2.02	2.09	2.33	2.37	2.41	2.25	2.24
Work to Rupture (cm <sup>2</sup> /g)	815	739	872	770	770	718	763	763	763
Burst Index (kPa <sup>2</sup> /m <sup>2</sup> )	3.19	3.30	3.10	3.52	3.29	3.09	2.77	3.61	3.24
Tear Index (mN <sup>2</sup> /m <sup>2</sup> )	6.88	6.34	6.44	8.20	8	8.62	8.37	8.12	10.33
Runnability (N <sup>2</sup> ·m <sup>2</sup> /1000g <sup>2</sup> )	405.86	387.34	372.35	374.49	479.37	466.64	437.38	402.35	381.96
Optical Properties									
ISO Brightness (4.57mm, %)	37.7	37.9	35.6	35.6	37.9	52.3	51.2	36.8	37.5
Opacity (%)	95.2	95.4	95.9	97.2	96.9	93.1	93.2	99.0	98.4
Scattering Coeff. (cm <sup>2</sup> /g)	516.5	515.9	329.9	35.4	401.1	505.0	505.0	496.3	468.3
Absorption Coeff. (cm/g)	67.8	73.2	83.1	83.1	33.2	115.9	115.9	33.4	33.4

Table 7  
The effect of peroxide bleaching on pulp and paper properties of treated and controlled pulps

Code	Treatment	Treated as per this invention with 1% NaBH <sub>4</sub>			Treated without buffers and chemicals		
		G2-4N	G2-4N-II	CB-JN	CB-JN-II		
Conditions							
MgSO <sub>4</sub> (%)	0	0	0.05	0	0.05	0.4	0.4
DTPA (%)	0	0	0.4	0	0	0.7	0.7
NaOH/H <sub>2</sub> O <sub>2</sub>	0	0	1.5	0	0	1.5	1.5
Silicate/I, (%)	0	0	5	0	0	5	5
H <sub>2</sub> O <sub>2</sub> (%)	0	0	25	0	0	25	25
Consistency (%)	0	0	80	0	0	80	80
Temperature (°C)	0	0	120	0	0	120	120
Retention Time (min.)							
Global Yield (%)	91.2	87.1	91.8	87.0	87.0		
Energy (kWh/ODMT)	1070	709	709				
<b>Dry Sheet Properties</b>							
<b>Structural</b>							
Basis Weight(g/m <sup>2</sup> )	59.99	61.32	58.61	60.45			
Bulk(cm <sup>3</sup> /g)	2.28	2.47	2.5	2.23			
Density (kg/m <sup>3</sup> )	438.50	405.96	391.76	449.13			
<b>Strength Properties</b>							
Tensile Index(N.m/g)	58.73	50.05	48.07	55.06			
Breaking Length(cm)	5.99	5.11	4.9	5.62			
Stretch(%)	2.02	2.16	2.41	2.12			
Work to Rupture (cm <sup>2</sup> g)	739	704	718	747			
Burst Index (kPa.m <sup>3</sup> /g)	3.30	2.84	2.77	2.96			
Tear Index (mN <sup>2</sup> .m <sup>1</sup> /Nm <sup>2</sup> )	6.34	8.06	8.37	7.82			
Runnability (Nm <sup>2</sup> .m <sup>1</sup> /Nm <sup>2</sup> )	372.35	402.40	402.35	430.57			
<b>Optical Properties</b>							
ISO Brightness(g.157mm, %)	35.6	64.7	16.8	52.9			
Opacity(%)	95.4	86.2	99	92.3			
Scattering Coeff. (cm <sup>2</sup> /g)	329.9	511.6	505	436.4			
Absorption Coeff. (cm <sup>-1</sup> /g)	73.2	11.9	115.9	29.6			
ISO-Brightness-Pad I	37.83	68.53	37.07	59.01			
ISO-Brightness-Pad II	79.08	93.59	77.52	90.64			
ISO-Brightness-Pad III	2.23	-1.98	3.15	-0.82			
	20.11	13.50	18.24	17.01			

Codes	Treated as per this invention with buffers and chemicals				Untreated	
	F1-5N	F2-4N	F3-4N	CB-3N	C-6N	
Conditions						
Initial pH	6.0	6.0	6.0	6.0	6.0	
Final pH	9.16	5.66	4.5	3.64	0	
Na <sub>2</sub> SiO <sub>3</sub> (%)	0.05	0.05	0	0	0	
Na <sub>2</sub> SO <sub>3</sub> (%)	1.50	1.40	0.4	0	0	
DITV(%)	0.4	0.4	0.1	0	0	
DI(%)	0.5	2	2	5	0	
Global Yield (%)	93.2	96.3	97.2	91.8	99.6	
Energy (kWh/ODMT)	1118.2	963.7	977	1181.3	869	1124.3
Pulp Properties						
Freeness (ml)	172	150	161	150	149	150
R14	15.4	14.5	16.9	15.1	11.5	12.7
1d/28	30.5	31.3	32.8	31.6	21.3	13.9
28/48	23.6	22.9	23.9	12.7	12.3	28.9
48/100	12.3	11.2	4.0	5.2	4.4	25.8
100/200	5.2	13.67	10.32	18.91	11.2	4.1
R200	13.05	1.47	1.53	1.54	1.38	16.10
Fiber Length (mm)	1.50	1.54	1.54	1.54	1.44	1.43
Total Ionic Content (mmol/kg)	248.68	170.73	107.67	93.51	137.98	
Dry Sheet Properties						
Structural						
Basis Weight(g/m <sup>2</sup> )	60.59	60.16	60.47	58.61	55.07	
Bulk(cm <sup>3</sup> /g)	2.40	2.33	2.60	2.55	2.85	
Density (kg/m <sup>3</sup> )	415.82	384.44	382.73	391.76	350.76	
Strength Properties						
Tensile Index(N/mm)	60.03	61.11	50.95	54.82	56.67	
Breaking Length(km)	6.13	5.20	5.75	4.90	4.74	
Stretch(%)	2.32	2.26	2.38	2.30	2.40	
Work to Rupture (cm <sup>2</sup> /g)	878	761	832	718	763	
Burst Index (kPa·m <sup>3</sup> /g)	3.39	3.42	3.00	3.17	3.25	
Tear Index (mN·m <sup>3</sup> /g)	7.64	7.50	9.00	8.94	8.31	
Lensile & Tear Index (N·m <sup>3</sup> /1000g)	458.63	458.32	458.55	490.09	480.41	
Optical Properties						
ISO Brightness(8.457nm,%)	43.5	44.2	48.0	47.2	36.8	
Opacity(%)	93.8	94	93.4	93.2	95.2	
Scattering Coeff. (cm <sup>2</sup> /g)	511.1	505.8	408.8	416.5	454.5	
Absorption Coeff. (cm <sup>2</sup> /g)	52.6	40.4	40.4	47.2	505.0	

Table 9  
The effect of peroxide bleaching on pulp and paper properties of treated and controlled pulps

Code	Treated as per this invention with buffers or chemicals					Treated without buffers or chemicals	
	F1-5N 5% H <sub>2</sub> O <sub>2</sub>	F1-5B	F2-4N 2% H <sub>2</sub> O <sub>2</sub> + 2% O <sub>2</sub>	F2-4N-A	F2-4N-B	CB-3N	CB-3N-B
Condition							
NaPSO <sub>4</sub> (%)	0	0.05	0	0.05	0.05	0.05	0.05
DIPA (%)	0	0.4	0	0.4	0.4	0.4	0.4
NaOH (1%)	0	0.7	0	0.7	0.7	0.7	0.7
Silicate (1%)	0	1.5	0	1.5	1.5	1.5	1.5
H <sub>2</sub> O <sub>2</sub> (%)	0	5	0	5	5	5	5
Consistency (%)	0	25	0	25	25	25	25
Temperature (°C)	0	80	0	80	80	80	80
Retention Time (min.)	0	120	0	120	120	120	120
Global Yield (%)	93.2	90.3	96.3	92.2		91.8	87.0
Energy (kWh/ODMT)	1118.2		977.0			709	
Dry Sheet Properties							
Structural							
Basis Weight (g/m <sup>2</sup> )	60.59	59.83	60.16	60.06	59.31	58.61	60.45
Bulk (cm <sup>3</sup> /g)	2.40	2.22	2.60	2.24	2.42	2.55	2.23
Density (kg/m <sup>3</sup> )	415.82	450.55	384.44	416.84	412.7	391.76	449.13
Strength Properties							
Tensile Index (N.m/g)	60.03	62.09	50.95	55.85	66.12	48.07	55.16
Breaking Length (km)	6.13	6.34	5.20	5.7	6.75	4.9	5.62
Stretch (%)	2.32	2.14	2.38	2.39	2.31	2.41	2.12
Work to Rupture (cm <sup>2</sup> /g)	878	812	761	814	931	718	747
Burst Index (kPa <sup>·</sup> m <sup>2</sup> /g)	3.39	3.82	3.00	3.14	3.95	2.77	2.96
Tear Index (N·m <sup>2</sup> /m <sup>2</sup> )	7.64	7.47	9.00	8.79	7.51	8.37	7.82
Runnability (N·m <sup>2</sup> /m <sup>2</sup> )	458.63	463.81	458.55	490.92	496.56	402.35	430.57
Optical Properties							
ISO Brightness (R=157nm, %)	43.5	61.5	48.0	61.8	66.2	36.8	52.9
Opacity (%)	91.8	81.6	93.4	85.1	83.3	99	92.3
Scattering Coeff. (cm <sup>2</sup> /g)	511.1	320.8	408.8	393.3	364.3	505	436.4
Absorption Coeff. (cm <sup>2</sup> /g)	52.6	10.9	40.4	11.8	10.0	115.9	29.6
ISO Brightness Pad	46.13	69.72	52.17	68.72	72.25	37.07	59.01
1 <sup>a</sup>	82.85	93.81	86.93	93.73	94.57	77.52	90.64
2 <sup>a</sup>	1.37	-2.08	0.6	-1.9	-2.22	3.15	-0.82
3 <sup>a</sup>	16.72	12.88	17.33	13.66	12.1	18.24	17.01

Table 10  
The effect of oxidizing agents on pulp pH and pulp and paper properties of treated and untreated pulps

Codes	Treated as per this invention with buffers or chemicals			Treated without buffers or chemicals			Untreated		
	11-4N	12-3N	13-4N	CB-3N	C-6N	C-6N	C-6N	C-6N	C-6N
Conditions									
Initial pH	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Final pH	6.0	5.28	4.96	3.64	0	0	0	0	0
HSO <sub>3</sub> :CII(CO <sub>2</sub> )II (%)	0.4	0.4	0.4	0	0	0	0	0	0
DTPA (%)	0.4	0.4	0.4	0	0	0	0	0	0
NaOII (%)	3.8	3.8	1.9	0	0	0	0	0	0
O <sub>2</sub> (%)	0	2	0	0	0	0	0	0	0
Global Yield (%)	95.1	94.6	95.1	91.8	99.6	99.6	99.6	99.6	99.6
Energy (kWh/ODMT)	13111.2	10909.9	902	1045.4	1450	1080.8	709	777.2	1638.7
Pulp Properties									
Freeness (ml)	146	150	190	150	104	150	149	150	127
R14	18.4	17.6	16.9	16.4	11.7	13.4	11.5	13.9	15.0
14/28	26.5	28.5	28.5	28.5	26.8	26.8	31.6	28.9	11.8
28/78	20.7	20.8	20.8	20.8	21.5	21.5	21.6	25.8	25.8
48/100	1.2	1.2	1.2	1.2	1.4.7	1.4.7	1.2.3	1.1.2	1.1.2
100/200	4.5	4.7	4.7	4.7	6.0	6.0	4.4	4.1	4.1
R200	17.91	16.19	16.19	16.19	19.3	19.3	18.91	16.10	16.10
Fiber Length (mm)	1.48	1.46	1.48	1.41	1.32	1.35	1.38	1.44	1.43
Total Ionic Content (mmol/kg)	160.4	155.39	155.39	131.69	93.51	93.51	137.98	137.98	137.98
Dry Sheet Properties									
Structural									
Dens. Weight (g/m <sup>2</sup> )	59.55	61.36	60.99	58.61	55.07	55.07	52.55	52.85	52.85
Bulk (cm <sup>3</sup> /g)	2.41	2.42	2.41	2.54	2.54	2.54	391.76	350.76	350.76
Density (kg/m <sup>3</sup> )	414.73	412.64	411.52	411.52	411.52	411.52	411.52	411.52	411.52
Strength Properties									
Tensile Index (N/m/g)	55.49	55.18	50.29	51.48	50.01	46.67	48.07	47.04	54.82
2.01	5.66	5.13	5.13	5.10	5.10	4.90	4.74	4.74	5.70
2.10	2.10	2.18	2.08	2.15	2.14	2.41	2.25	2.25	2.24
6.87	7.07	7.16	6.92	7.18	7.18	7.63	7.63	7.63	2.14
3.14	3.02	2.72	2.88	2.78	2.44	2.77	2.67	2.67	3.24
8.47	8.25	8.47	8.06	8.27	8.62	8.37	8.12	8.12	10.33
453.35	455.24	425.96	414.93	413.58	402.30	402.35	381.96	381.96	628.06
Optical Properties									
ISO Brightness(B-457nm, %)	35.5	34.2	34.1	34.2	39.6	38.8	36.8	37.5	55.1
Opacity (%)	97.8	98.0	98.0	98.1	98.3	98.3	99.0	98.4	93.6
Scattering (oelf, cm <sup>2</sup> /g)	51.1	484.4	413.2	428.1	495.7	485.9	505.0	496.3	468.3
Absorption Coeff. (cm/g)	92.2	99.2	99.2	89.8	115.9	115.9	133.4	133.4	92.9

CLAIMS

1. A process by which lignocellulosic pulp fibers are produced at low specific refining energy and high yield, characterized by the following steps:

- (i) mixing the lignocellulosic pulp fibers with a buffer or chemicals to adjust the pH of the pulp while maintaining the pulp at high consistency,
- (ii) submitting the pulp to high temperature for times and chemical charges sufficient to reduce the long range crystalline structure of the cellulose component of wood, and
- (iii) subsequently subjecting the lignocellulosic pulp fibers to refining to produce a pulp with the desired end-product properties.

2. A process of claims 1, characterized in that said pulp fibers are lignocellulosic pulp fibers obtained after impregnation of wood chips in a single or multistage impregnation with water, sulfite, bisulfite, peroxide solution, sodium borohydride and sodium borohydride-caustic-sulfite liquor followed by refining.

3. The process of claim 1, characterized in that said lignocellulosic material is a washed pulp or pretreated pulp with metal complexing agents to remove metal ions prior to the treatment.

4. The process of claim 1, characterized in that said lignocellulosic pulp fibers are whole pulps from main line refining lines or are long fibers or rejects obtained from screening and cleaning stages.

5. The process of one of the preceding claims, characterized in that the chemical or buffer used to adjust the pH is an acid such as HCl, H<sub>2</sub>SO<sub>4</sub>, and H<sub>2</sub>CO<sub>3</sub>.
6. The process of one of claims 1-4, characterized in that the chemical or buffer used to adjust the pH is a base such as NaOH, Ca(OH)<sub>2</sub>, and Na<sub>2</sub>CO<sub>3</sub>.
7. The process of one of claims 1-4, characterized in that the buffer or chemical used is a mixture of Ca(OH)<sub>2</sub> and CO<sub>2</sub> (g) or H<sub>2</sub>CO<sub>3</sub>.
8. The process of one of the preceding claims, characterized in that the chemicals used are oxidizing agents to adjust the pH below 7 which is, for instance, a mixture of oxygen (O<sub>2</sub>) and peroxide (H<sub>2</sub>O<sub>2</sub>), a mixture of ozone (O<sub>3</sub>) and peroxide (H<sub>2</sub>O<sub>2</sub>) and peracids (H<sub>2</sub>SO<sub>4</sub>-H<sub>2</sub>O<sub>2</sub>, CH<sub>3</sub>COOH-H<sub>2</sub>O<sub>2</sub>).
9. The process of one of the preceding claims, characterized in that the chemical used to adjust the pH above 7 is an oxidizing agent which is, for instance, peroxide (H<sub>2</sub>O<sub>2</sub>).
10. The process of one of the preceding claims, characterized in that the chemical used to adjust the pH above 7 is a reducing agent such as sodium sulfite (Na<sub>2</sub>SO<sub>3</sub>), sodium borohydride (NaBH<sub>4</sub>) and formamidine sulfuric acid (FAS).
11. The process of one of the preceding claims, characterized in that the chemical used to adjust the pH below 7 is, for instance, a reducing agent such as bisulfite (MHSO<sub>3</sub>) or acid sulfite (H<sub>2</sub>SO<sub>3</sub> + MHSO<sub>3</sub>) (where M = Base = 1/2Ca<sup>2+</sup>, 1/2 mg<sup>2-</sup>, Na<sup>+</sup>, NH<sub>4</sub><sup>+</sup>) and dithionite or sodium hydrosulfite (Na<sub>2</sub>S<sub>2</sub>O<sub>4</sub>).
12. The process of one of the preceding claims, characterized by the subsequent steps of screening, cleaning, dewatering and

brightening or bleaching sequences to upgrade further the brightness of the pulps.

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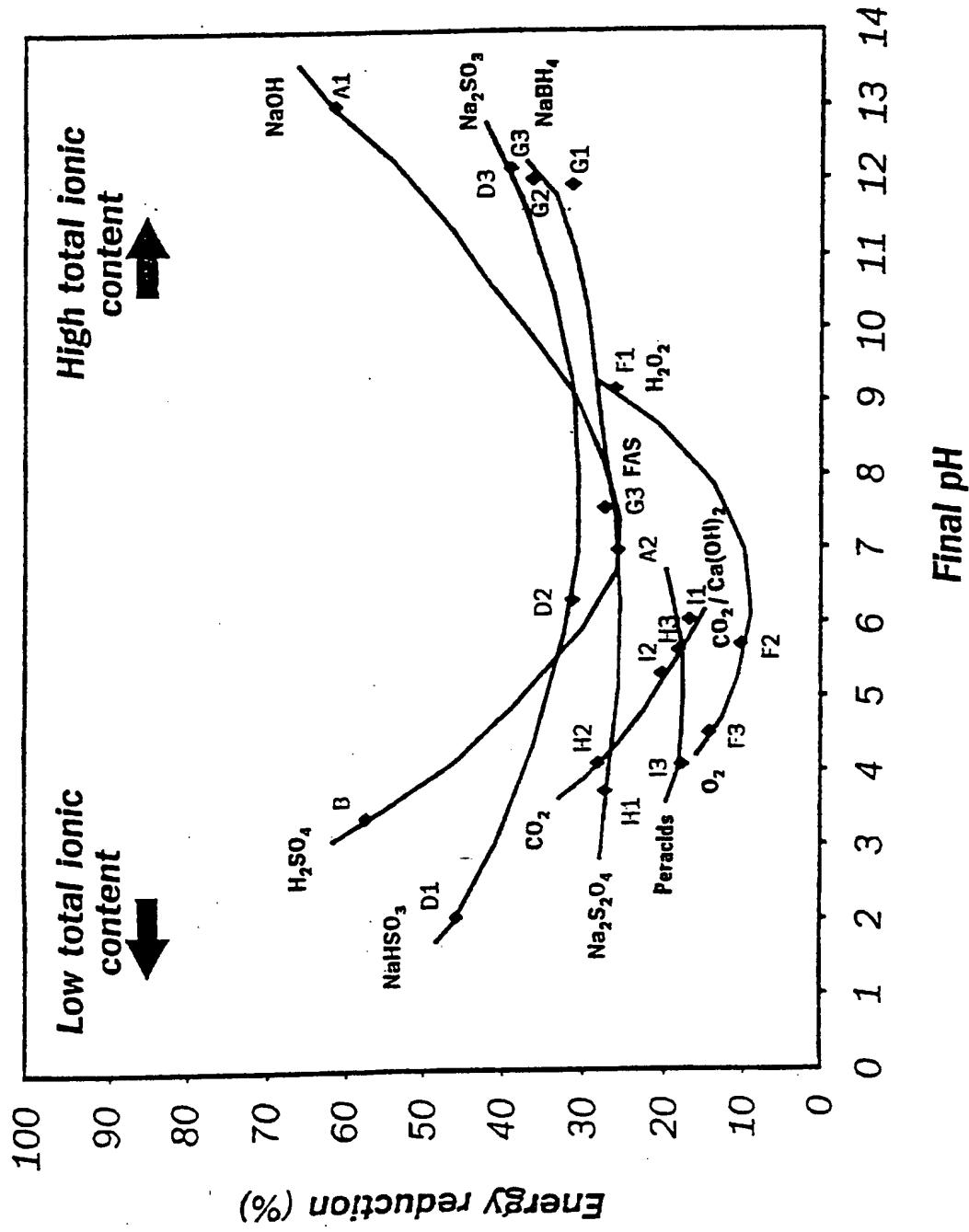


Figure 1.

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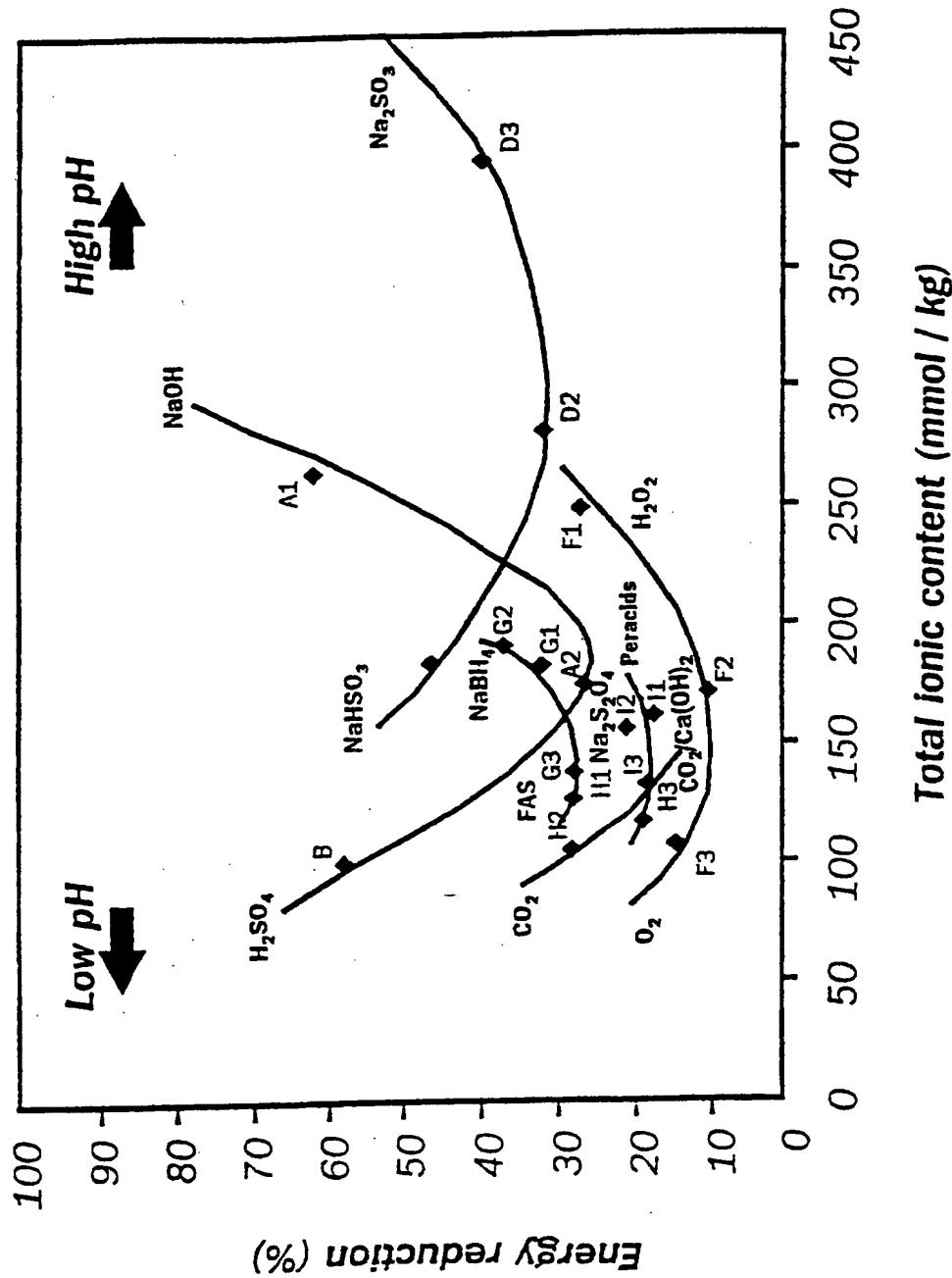


Figure 2.

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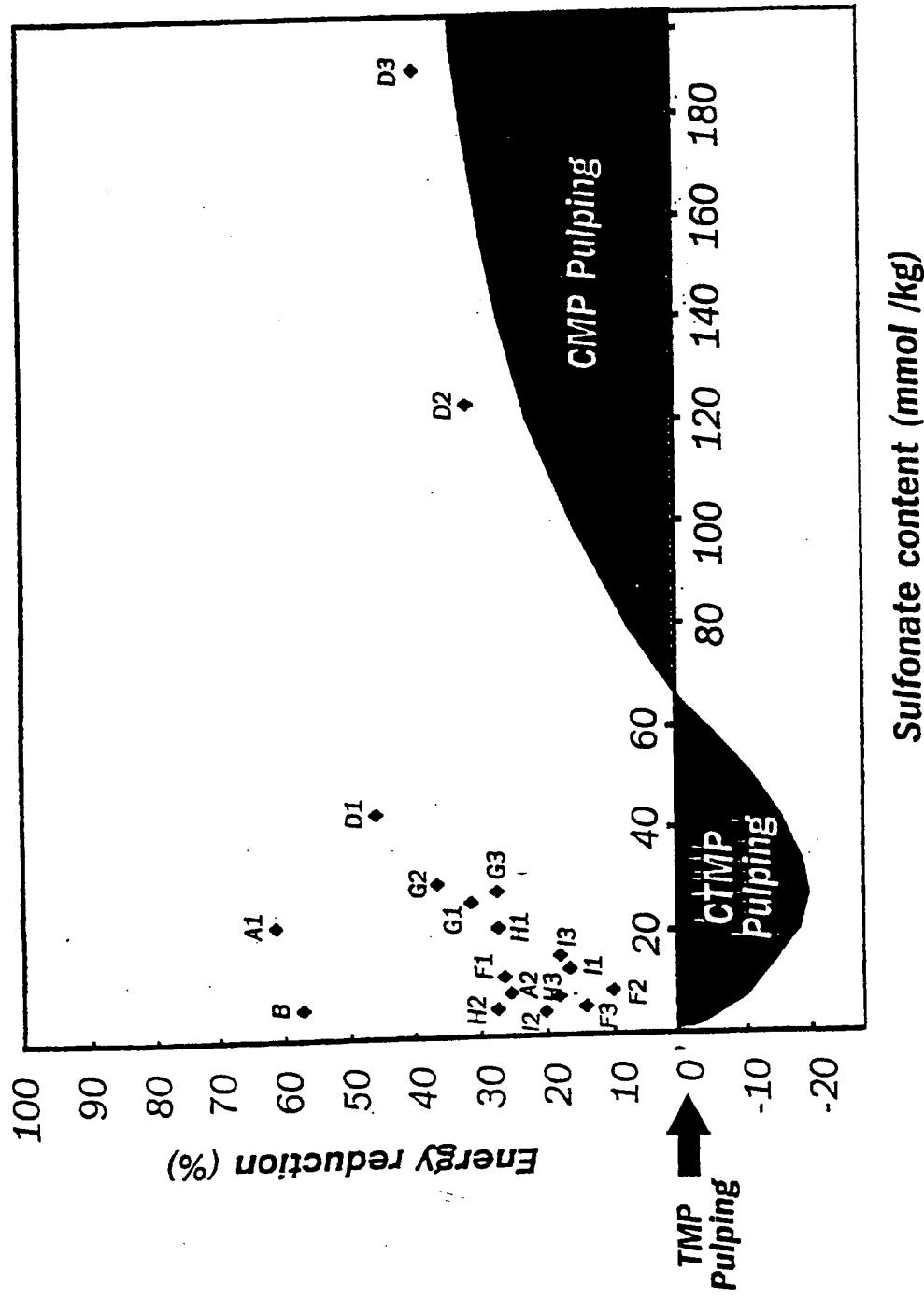


Figure 3.

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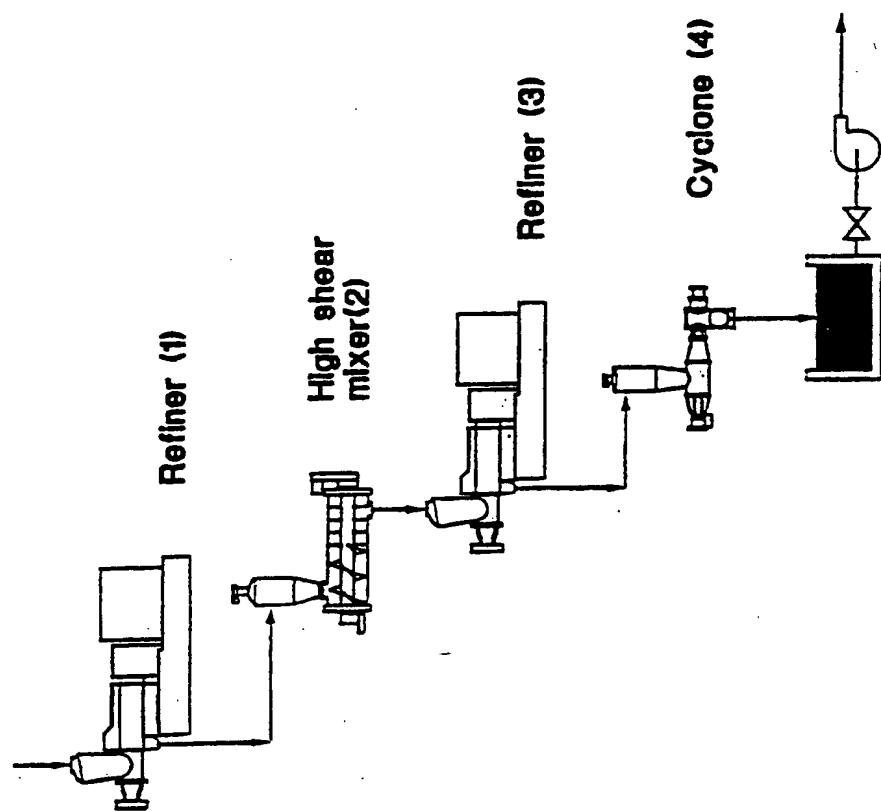


Figure 4.

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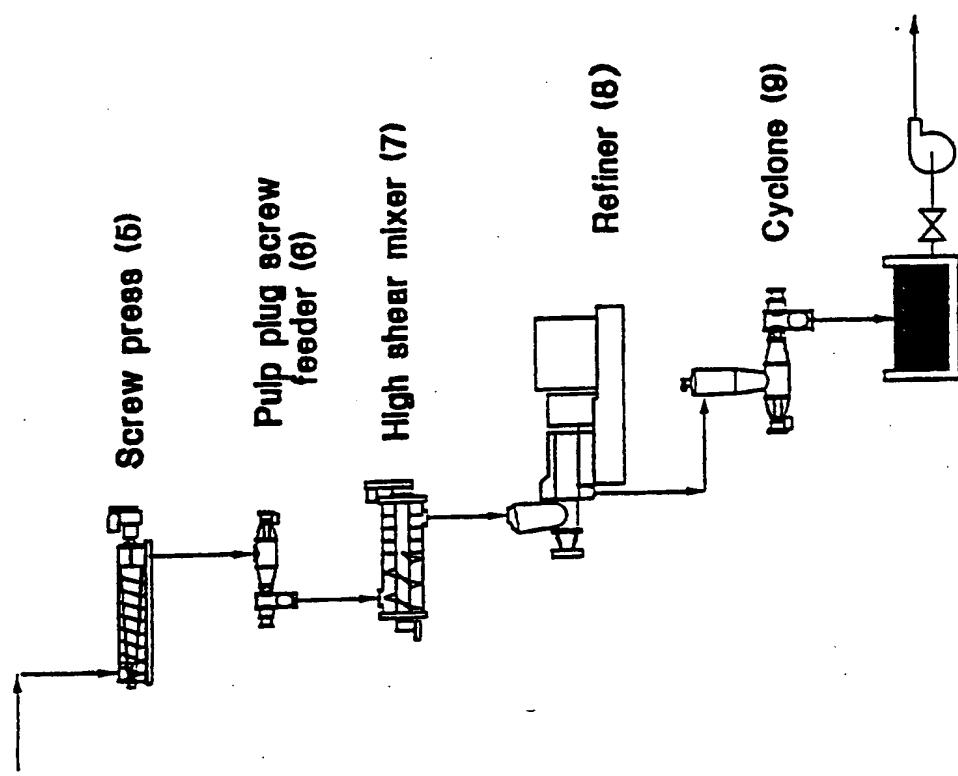


Figure 5.

# INTERNATIONAL SEARCH REPORT

Application No

PCT/IB 95/01140

A. CLASSIFICATION OF SUBJECT MATTER  
 IPC 6 D21B1/02 D21C3/26 D21C9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
 IPC 6 D21B D21C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 030 778 (THE ONTARIO PAPER COMPANY LTD.) 24 June 1981 see page 5, line 11 - page 7, line 20 ---	1,2,4,6, 10
X	US,A,3 597 310 (SUMI YUICHIRO ET AL) 3 August 1971 see column 2, line 51 - line 66 see column 3, line 62 - column 4, line 7; examples ---	1,2,4,6, 10,12
A	WO,A,87 03022 (SUNDS DEFIBRATOR) 21 May 1987 see page 3, line 3 - page 4, line 2 ---	1-4,9,12
A	WO,A,92 20855 (SUNDS DEFIBRATOR IND AB) 26 November 1992 see the whole document -----	1-6,10, 12



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

\* Special categories of cited documents :

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Date of the actual completion of the international search

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